THE FIGHT AGAINST INFECTION

BY W. W. KEEN, M.D., LL.D.
Emeritus Professor of Surgery, the Jefferson Medical College, Philadelphia.

THE conquest of infection was a most urgent problem long before the Great War. Early experiences in the war upset all our notions as to how it could be conquered. Of late we have seen a great light, as I shall show.

Roughly speaking we differentiate Medical Infections and Surgical Infections according as the germs cause what are deemed medical or surgical diseases. Thus typhoid and typhus, dysentery, cholera, and plague are medical infections. The surgical infections include tetanus or lockjaw, gas gangrene and the many results of inflammation, such as abscesses, inflammations attacking special organs, as the appendix or the gall-bladder, and especially the inflammation attacking wounds caused by the "pyogenic," i. e., "pus-producing" germs.

Some germs produce both medical and surgical troubles; *e. g.*, the tubercle bacilli cause consumption of the lungs, a strictly medical disease; and also tuberculous diseases of the bones and joints which are strictly surgical. The typhoid bacilli every now and then produce abscesses and diseases of the bones and joints which are surgical.

Sometimes a "mixed infection" occurs. For example, the so-called "cold abscess" (because it is not hot like ordinary abscesses) is caused by tuberculosis of the spine (Pott's disease) or hunchback. If such an abscess bursts the ordinary germs of suppuration enter and produce "pus" mixed with the products of the tuberculous affection. Until the abscess burst it was neither red nor hot, nor did the patient have any "fever." The moment the pus-producing germs entered, causing a mixed infection, redness, heat, and "hectic fever" set in.

Some infections (*e. g.*, the tuberculous) pursue a pro-

longed chronic course covering months and even years. Some attack with almost lightning-like rapidity. For instance the ordinary pus-producing germs often destroy life in a week, while the gas-bacillus may kill within less than twenty-four hours. This bacillus is very common in the present war, whereas I never saw a single case during the Civil War. Sometimes the gas accumulates in the tissues to such an extent that an amputated limb may float.

We owe our very first victories in the fight against infection to Louis Pasteur of France. His studies of fermentation of beer, wine, butter, etc., revealed the fact that it was not due to ordinary chemical action, but was a vital process—a disease, one might say—due to the growth of visible plants such as we are familiar with in the yeast plant, the mother of vinegar, etc. This suggested to his fertile mind that diseases of animals and man might be due to those microscopic plants (bacteria) which had already been observed in the blood and the organs of sick animals and men. Accordingly he investigated a disastrous disease, which was then decimating the flocks and herds of France (and found not a few human victims), called " anthrax " in animals and " wool-sorters disease " in man. He proved that the disease both in animal and man was due to germs invisible to the naked eye but easily seen by the microscope. They resembled small rods—the anthrax bacilli.[1] He also proved that puerperal fever—that former horrible bane of motherhood—was due to a germ which was carried ignorantly and innocently from one patient to another by the doctors and nurses.

Until bacteriology proved that various diseases were caused by certain bacteria, the origin and means of diffusion of these diseases were unknown and often mysterious. When the bacteria of various diseases were discovered, these hitherto concealed and masked unknown foes were dragged into the light, their life histories studied in test tubes and in living animals, what would help or hinder their growth, what would kill them without injuring the patient, and how their ravages could be avoided, and whole communities saved from epidemics and pestilences.

The earliest use of the word " bacteriology " as a science dates only from 1884. Before that date a number of differ-

[1] " Bacteria " is the term used to denote in a general way all the various kinds of " germs." " Bacilli " are bacteria in the form of little rods.

ent bacteria, such as those of typhoid, suppuration, glanders, tuberculosis, tetanus, diphtheria, etc., had been discovered but bacteriology as a science, i. e., the orderly arrangement and classification of these various bacteria in relation not only to the diseases they produced but to each other in genera and species, did not exist. Before 1884 the different bacteria were like stones scattered in a field wholly unrelated to each other. When these stones were gathered together and made into a building they took on a wholly new meaning. Bacteriology thirty years ago was the most youthful science. It has grown so rapidly that it is now recognized as the most important discovery ever made in pathology and one of the most important in all medicine.

As early as 1867—just fifty years ago—Lister had seen these undiscovered and unknown "germs" by his wonderful prescient imagination. Suspecting their presence by their effects he took active steps to prevent their entrance into wounds. His first paper was on a new treatment of compound fractures.[2] By preventing any germs from gaining access to such a fracture he found that he could prevent infection and then healing took place as if it were a simple fracture. In successive papers, the result of his experimental researches, he gradually perfected his treatment so that normal healing without infection, and therefore without suppuration or fever has become the rule. Later, asepsis was a natural sequence of antisepsis. Asepsis endeavors, especially by heat and without chemicals, to sterilize everything in advance so that there shall be no germ present to gain access to the wound. Antisepsis endeavors by chemical means, carbolic acid, corrosive sublimate, etc., to kill any germs that have already gained access to the wound and any that might later try to gain access to it.

As a result of this prevention of the access of bacteria to accidental and to surgical wounds the mortality of compound fractures and of ovariotomy, for instance was reduced from two out of every three to one or two out of every hundred, and operations for appendicitis, the removal of tumors, cancer, etc., had their mortality so reduced that it is now almost negligible.

[2] A "compound" fracture is one in which the skin is broken and the air and bacteria get access to the wounded tissues. A "simple" fracture is one in which the skin is intact and the bacteria cannot reach the wound. Hence a "simple" fracture heals without suppuration or fever; a "compound" fracture always used to be followed by both.

Hygiene has developed with almost equal rapidity, for engineering and especially bacteriology are the basis of most of its modern development.

But the bacteriologists have not been content with discovering the causes of these various diseases. They have discovered also how to produce antidotes, i. e., antitoxins, to combat the poisons (toxins) produced by the various bacteria. Here are some striking illustrations:

By vaccinating patients against dysentery the ravages of that disorder have been enormously diminished during the present war.

By vaccinating against typhoid fever that disease had been practically abolished in the American Army in time of peace. Even in war, with all its disorder and confusion, none of the present European armies has suffered from the ravages of typhoid as compared with our experience during the Spanish-American War. In that war *every fifth soldier,* twenty per cent., contracted typhoid! In the present war the British Army of certainly five million men has had less than five thousand cases, i. e., less than *one case in every thousand men,* instead of a million, or *one case in every five men,* as we had in 1898. Moreover, among the men *not* protected by the antityphoid vaccination the percentage of *cases* of typhoid was *fifteen times greater* and the percentage of *deaths* was *seventy times higher* than among those who had been so protected.

Tetanus or lockjaw, one of the most horribly painful and deadly diseases I have ever seen, has usually in war a mortality of nine out of every ten men attacked. It has been practically totally abolished on both sides in the present war. Every wounded man is given a protective hypodermic of the antitoxin at the very first dressing station. Unless this medical aid comes too late—as in the case of men who have lain for hours or even a day or two in " No Man's Land " between the trenches—he is practically sure of escaping lockjaw although the germs of the disease abound in his clothing, on his skin, in the mud through which he wades, or in the earth on which he lies.

For many years it had been known that men working in stables were peculiarly liable to contract lockjaw after a cut or an abrasion, but until Nicolaier in 1884 discovered the germ of tetanus we never could even guess why.. Now it is perfectly clear. The bacilli of tetanus exist normally in the

intestines of horses. Stables, therefore, are widely and thoroughly infected. Moreover, it is a curious fact that while these bacilli normally find a congenial home in the *intestines* of the horse and he is not any the worse for their presence, if the horse himself is wounded and the tetanus bacilli get into the *wound* he will contract tetanus. Many horses have died from this cause in the present war.

It will be observed that all of the preceding has to do with the prevention of infection. Lister and the bacteriologists have won victory after victory in this field.

But for well-nigh half a century surgery has been anxiously seeking to solve another far more difficult problem, only to fail again and again. This problem is not how to *prevent* but how to *vanquish* infection. By suitable disinfection of instruments, dressings, the skin of the patient and the hands of the surgeon, we could almost promise speedy and certain recovery after operations deliberately done, or accidents promptly cared for.

Even in civil life, if as a result of accidental causes or through ignorance or neglect no preventive measures had been instituted before the surgeon saw the case, and especially if any considerable time had elapsed, the wound was sure to be widely infected and disaster was at hand.

But in the present war infection has been overwhelming. Without exception the testimony is that no surgeon in civil life nor even any surgeon in previous modern wars had ever seen or had to cope with such incredible and almost malignant infection. No wonder that our good old preventive weapons failed us.

The soil of France and Belgium has been cultivated and roamed over by cattle, sheep, horses, swine and men since before Caesar wrote his Gallic War. For over two thousand years the bacilli of tetanus, gas gangrene, and the pus-producing bacteria of many kinds have flourished luxuriantly in this soil. The soldier marching in the dust and mud, with his skin begrimed and his clothing bedaubed with this bacteria-infected dirt, therefore has every element for unlimited infection at hand. When hit, especially by a fragment of shell, some of his clothing or of his skin is almost sure to be carried deep into the wound and some of these bits of skin, or clothing, or of the shell, all heavily infected, are very likely to lodge. If the bone is shattered the fragments

are projected in different directions as a shower of secondary missiles. The result is a deep irregular lacerated wound with many recesses or pockets in between the torn muscles and the raggedly broken ends of the bone. Blood—the very best culture medium for bacteria—fills every interstice of the wound. In this medium the bacteria soon multiply with an exceeding and ever increasing rapidity,[3] soon permeate the whole wound and then invade the surrounding walls of the irregular cavity. These walls of soft muscular tissue, torn and devitalized by the sudden violence of the missile, soon die and are sloughed off, thus still further promoting the growth of the bacteria.

If such a wound can be cared for within a few hours, though it may be difficult, it is still possible to disinfect it, but by the end of twenty-four hours the bacteria are too numerous to count in the field of the microscope. They invade every nook, corner, and cranny of the wound and all the tissues around the wound. Then indeed infection becomes "rampant." In spite of the wonderful healing powers of nature, which even in these conditions is able to cure not a few cases, in the others matters go from bad to worse, high fever sets in, often secondary hemorrhages[4] take place, bed-sores appear, the mind wanders, unconsciousness follows, and death soon closes the scene. During the Civil War how many, many such cases of "blood poisoning," i. e., pyemia, did I see!

Think how we treated these cases during the Civil War! We knew absolutely nothing about bacteria and their dangers or about real infection and real disinfection. Anything which covered up a bad smell we then called a disinfectant. We thrust our undisinfected fingers into wounds, cut with undisinfected knives, tied arteries and sewed wounds together with undisinfected silk and dressed them with undisinfected cold water dressings—until pus began to flow—and then dressed them with infected and infecting flaxseed poultices! Is it any wonder that pyemia had, to our shame, a mortality of 97.4 per cent.?

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[3] An idea of the almost unbelievable rapidity of the growth of some bacteria is obtained by the statement of Belfield that one microscopic bacterium of which it takes 40,000,000 to weigh a grain, if given room enough and food enough for three days, would weigh 800 tons!

[4] Called "secondary" to distinguish it from the "primary" hemorrhage which occurs at the time of the infliction of the wound, while secondary hemorrhage does not usually occur until some days later.

When pus began to flow freely we made a "counter-opening" at the most dependent part of the wound to let the pus escape. The common-sense treatment of course would have been to *arrest the continuous formation of the pus.* But we had no means by which we could accomplish this most desirable result.

When the Great War broke out both the aseptic and the antiseptic methods were applied, and both failed miserably. It seemed as if the very foundations of Lister's work were crumbling away. Many men were working at the problem day and night, in many a laboratory in the field and at home. New methods were tested—some seemed at first to promise well,—but most of them were quickly or gradually abandoned as unequal to the task.

But now Lister and Pasteur and Antisepsis (and Asepsis in its proper field) have come into their own again. We have won the fight against even rampant infection.

We have found an efficient antiseptic and we have found a new technic of its application so that the Verdun of Infection has capitulated.

Dakin in Leeds and later in the Herter Laboratory in New York, and Lorrain Smith, with three colleagues in Edinburgh, both instituted independent researches on the value of a formerly used but long neglected antiseptic, the hyposulphite of soda or "bleaching powder." This, under the name of "Labarraque's solution," had been used years ago, but was a historical more than an actual disinfectant. The Edinburgh men produced a powder and a liquid each with 0.5 per cent. of hypochlorite and Dakin a similar hypochlorite solution of the same strength.

Fortunately Dakin and Carrel came together first in New York and later collaborated at the hospital in Compiègne—a happy "conjunction" of two major planets. The chemist and the experimental surgeon—the one English by birth, but working later in America and now in France; the other French by birth, working later in America and now in France, both in the service of that splendid American charity, the Rockefeller Institute, which supports the hospital at Compiègne—have elaborated the antiseptic and the method by which infection has now been conquered.

At La Panne, Depage, the foremost Belgian surgeon, has thoroughly mastered the Carrel-Dakin treatment, and this

and the hospital at Compiègne are the two centers from which the technic is being diffused all over the world.

On the grounds of the Rockefeller Institute the Rockefeller Foundation is building a temporary hospital where Carrel and Dakin, while on leave, will teach our American military surgeons the details of this treatment. On the strictness with which such details are carried out depends the success of the method.

One fact will well illustrate what this treatment has accomplished. Dr. C. L. Gibson of New York, at La Panne, saw eighty cases of compound fracture of the thigh. Each case was dressed before his eyes and *not a drop of pus* was to be seen! Even in time of peace, with every facility of the best equipped hospital, I should consider that an unexpected and almost an unattainable triumph.

What now is Carrel's technic? The wound is thoroughly cleansed; X-Ray pictures and a most careful examination are made to ascertain whether foreign bodies are still in the wound, for if a bit of shell—or still worse, of clothing or skin—is present the wound will never heal until this has been removed. If the missile has passed completely through, thus providing a "counter-opening," this is closed in an appropriate way. A reservoir containing Dakin's fluid is hung one meter (39 inches) above the level of the wound. From this reservoir one large tube controlled by a pinch-cock leads to a glass tube with several branches like the teeth of a comb. From these multiple tubular teeth several small rubber tubes are so disposed as to reach every part of the wound. The far ends of these small tubes are tied, but the fluid escapes through several very small holes one millimeter (1-25 of an inch) in diameter in the sides of the tube, and so is kept constantly in contact with the entire internal surface of the wound.

Every two hours day and night for only one or two seconds, the pinch-cock is opened and a little more fluid is sprinkled in minute streams through the side holes of the small tubes to every part of the wound. It is not intended that the fluid shall run over and soak dressings or the bed. It is only intended to fill the wound in every possible recess, and to keep the antiseptic fluid in contact with the entire inner surface of the wound all the time. By this means, wherever there are any bacteria in any part of the wound the antiseptic fluid is constantly at work destroying them. The

aseptic technic must be perfect. Not even a gloved finger is allowed to touch the wound. Everything, dressings, tubes, etc., all are handled by thoroughly disinfected forceps.

Every second day a microscopic examination of the discharge from the wound is made in order to count the number of the bacteria. At first they are innumerable. From day to day they diminish and in a short time but few are found. When they have practically disappeared for several days the wound, which so far has remained open, is closed by sutures, and it quickly heals. In four hundred cases Dehelly, one of Carrel's assistants, said that all but six had healed perfectly!

Carrel and Count du Noüy, a French physicist, have devised what may be called "Mathematical Surgery." The exact size of the wound, when it has healed in its depths and become only a surface wound, is measured by a "planimeter" every second day. This instrument enables one to measure accurately the number of square centimeters there are in the most irregularly shaped wound. A "curve of healing" can then be plotted on a chart. After the first few observations showing the rate of diminution in surface area of the wound, one can complete the "calculated curve" and fix definitely the day when the wound will be completely healed. If no accidental reinfection occurs, the "actual" curve practically coincides with that predicted by calculation. If a slight reinfection retards healing, as soon as the reinfection is conquered the "actual" curve will often "catch up" and overtake the "calculated" curve.

This technic is plainly adapted to present conditions, but it is wholly at variance with the old technic of the Civil War. Then a "counter-opening" at the lowest point was always made to favor the escape of every drop of pus; to prevent the pus from escaping would then have promoted its diffusion among the soft tissues. Now the pus is purposely kept as in a cup, in order to assure the continuous action of the antiseptic everywhere, for now this antiseptic so used destroys the pus—to use a now familiar financial phrase—"at the source."

The results are equally desirable from the medical and the military point of view. The surgeon has the enormous satisfaction of saving many limbs from amputation, for *eighty per cent.* of amputations are the result of infection; of saving many gallant lives, and in a far shorter time than formerly. The commanding general sees his wounded re-

turning in a steady stream to the trenches instead of wandering off into civil life mutilated and only partly able to earn their living, or being carried to the cemetery.

This conquest of infection will go far to mitigate the evils of the war. It is a permanent gain for humanity for all time. The civil surgeon, the employer, the employee, the publicist, the sanitarian, the lover of his kind—all have cause for rejoicing. The patriots of the three great modern democracies may well rejoice in that two of them gave birth to the two men and America supplied the golden opportunities.

W. W. KEEN.